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ABSTRACT

This paper describes the effects of science teacher subject-matter knowledge on classroom discourse at the level of individual utterances. It details one of three parallel analyses conducted in a year-long study of language in the classrooms of four new biology teachers. The conceptual framework of the study predicted that when teaching unfamiliar subject matter, teachers would use a variety of discourse strategies to constrain student talk to a narrowly circumscribed topic domain. The paper includes the results of an utterance-by-utterance analysis of teacher and student talk in a 30-lesson sample of science instruction. Data are broken down by classroom activity for a number of measures, including duration of utterances, domination of the speaking floor by the teacher, frequency of teacher questioning, cognitive level of teacher questions, and student verbal participation. When teaching unfamiliar topics, the four teachers in this study tended to talk more frequently and for longer periods of time, ask questions frequently, and rely heavily on low cognitive-level questions. The rate of student questions to the teacher was found to vary with the classroom activity. In common classroom communicative settings, student questions were less common when the teacher was teaching unfamiliar subject matter. The implications of these findings include a suggestion that teacher knowledge may be an important unconsidered variable in research on the cognitive level of questions and teacher wait-time. (Author/CW)

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Teacher Knowledge and the Language of Science Teaching

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ABSTRACT

This paper describes the effects of science teacher subject-matter knowledge on classroom discourse at the level of individual utterances. It details one of three parallel analyses conducted in a year-long study of language in the classrooms of four new biology teachers. The conceptual framework of the study predicts that when teaching unfamiliar subject matter, teachers utilize a variety of discourse strategies to constrain student talk to a narrowly circumscribed topic domain. This paper includes the results of an utterance-by-utterance analysis of teacher and student talk in a 30-lesson sample of science instruction. Data are broken down by classroom activity (e.g., lecture, laboratory, group work) for a number of measures, including mean duration of utterances, domination of the speaking floor by the teacher, frequency of teacher questioning, cognitive level of teacher questions, and student verbal participation. When teaching unfamiliar topics, the four teachers in this study tended to: talk more often and for longer periods of time, ask questions frequently, and rely heavily on low cognitive-level questions. The rate of student questions to the teacher was found to vary with classroom activity. In common classroom communicative settings, student questions were less common when the teacher was teaching unfamiliar subject matter. The implications of these findings include a suggestion that teacher knowledge may be an important unconsidered variable in research on the cognitive level of questions and teacher wait-time.

Teacher Knowledge and the Language of Science Teaching

This paper describes the effects of science teacher subject-matter knowledge on classroom discourse at the level of individual utterances. This analysis complements broader analyses of the effects of teacher knowledge at the levels of conversations and multiple-lesson units of instruction, described elsewhere (Carlsen, 1988, 1989a, in press).

The conceptual framework of this study is a sociolinguistic model relating the scientific knowledge of new biology teachers to the structure of classroom discourse: it predicts that teachers will use discourse strategies that vary as a function of their subject-matter understanding. When teaching unfamiliar topics, the framework predicts that teachers will use instructional and discourse strategies that constrain students' opportunities to ask questions. Such strategies may serve to protect teachers from having classroom conversations move into unfamiliar areas. Teacher control of discourse may have pedagogical advantages, but it may also inadvertently undermine the teacher's intention to model the syntax of scientific inquiry.

The analyses in this paper utilize as data every audible recorded teacher utterance and every teacher-acknowledged student utterance in approximately 1500 minutes of recorded classroom conversation, a total of over 4000 utterances. The linguistic imprecision of the term utterance is acknowledged and has been addressed empirically. Using a computer and time-coded transcripts, a variety of algorithms were tested to computationally segment verbatim transcripts into utterances (Carlsen, 1989b). As a result of that work, an utterance is operationally defined here as a stretch of speech terminated by a pause of three seconds or a change in speaker. Although this

definition is insensitive to the social functions of talk (in contrast to, for example, the treatment of utterances in speech act theory), it provides several advantages in this analysis.¹ For example, teacher domination of the speaking floor could be easily calculated in a variety of ways.

Pilot Study

A number of teacher strategies for constraining classroom conversations were identified during a pilot study, which contrasted lectures on familiar and unfamiliar topics by six new biology teachers (Carlsen, 1987). Compared to lectures on familiar topics, lectures on unfamiliar topics tended to: be dominated by the teacher (as measured by mean length of utterances, total number of utterances, and other measures), include more teacher questions, include a higher ratio of low cognitive level to high cognitive level questions, elicit fewer student questions and student utterances in general, and elicit shorter student remarks. Analysis was done using time-coded verbatim transcripts of pairs of lessons taught to the same groups of students in public school classrooms.

Although the pilot study findings were intriguing, they were not generalizable for two reasons. First, the pilot study was exploratory and emergent in design, rather than hypothesis-testing. Consequently, it was possible that the findings represent error variance, not knowledge effects. Second, the pilot study investigated a small number of lessons, all lectures. A broader study of a variety of types of instruction was therefore undertaken to provide a more general description of the effects of teacher knowledge on science instruction.

Design and Procedures

The effects of teacher subject-matter knowledge were documented in a

year-long study of four new biology teachers. The teachers, all of whom had majored in biology, taught half days in public secondary schools as part of a master's-level teacher education program. As the teachers' university subject-matter supervisor, I regularly visited one of their biology classes and audiotape-recorded 12-15 lessons over the course of the school year. Visits were scheduled to sample a number of curricular topics over a range of teacher subject-matter expertise. The teachers in the study were aware of the discourse and curriculum orientations of the study, but were unaware that relative subject-matter knowledge was an independent variable.

Teacher subject-matter knowledge was assessed in several ways, including a card-sort task of 15 biological topics by self-reported subject-matter knowledge (administered as part of a curriculum workshop during the summer prior to the study), interviews on teachers' sources of knowledge (conducted at the end of the school year), and analyses of undergraduate and graduate transcripts. The principal contrasts in the study were within-teacher contrasts, comparing planning and teaching by individual teachers across a number of topics. Because of the wide variety of topics taught in high school biology, although all of the teachers were knowledgeable about many topics in biology, none had expertise on all of the topics that they were expected to teach.

Audiotape recordings of science lessons were made using a two-track portable tape deck and two microphones, one a wireless unit worn by the teacher. All transcription was done by the investigator. Transcripts of lessons were stored on a computer using a format that provided flexibility of analysis. The transcripts included data on the content of speech (e.g., the words being uttered, some paralinguistic features), the context (e.g., the

type of classroom activity being conducted, the name of the speaker), and the time of utterance (data from which pause lengths, rate of speech, and other measures could be computed). Software was written to print transcripts using theoretically-sensible transcription rules, and models of classroom discourse could be played back on the computer screen in real time or at an accelerated rate. The software was also used to annotate transcripts. For example, teacher questions were coded by cognitive level while examining the questions in their conversational context.² Finally, statistics and graphs summarizing classroom talk could be easily generated.³

For each of the four teachers in the study, two relatively high-knowledge topics and two relatively low-knowledge topics were identified. For each of these four topics, two lessons were tape-recorded; consequently, data can be viewed as coming from a factorial design: 2 lessons x 2 topics x 2 knowledge levels x 4 teachers. For one teacher, Ms. Ross, two low-knowledge audiotapes (on different topics) were unusable, leaving a total of 30 lessons for this analysis. Because the teachers had similar educational backgrounds and because the focus of this paper is on within-subject variation, absolute levels of teacher subject-matter knowledge are not discussed here. As a rough metric, however, the teachers had all had several undergraduate or graduate-level courses (and, in some cases, research experience) on their high-knowledge topics and one or no college courses on their low-knowledge topics.

Among the contexts that are important in this analysis is the classroom activity, defined elsewhere in an analysis of these teachers' lesson plans and teaching (Carlsen, 1989a). Activities of 29 types were identified in this research, but communicatively-similar activities are combined in this paper to make the tables easier to interpret. Examples of combined activities are

student Group work, teacher Instructions, Lectures, and Laboratories.

Results

Four general questions organize the findings in this paper. First, what is the relationship between teachers' subject-matter knowledge and the amount they talk during a lesson? The conceptual framework predicts that teachers will talk more when they have low subject-matter knowledge. Dominating conversation is one way of controlling discourse. Findings 1 and 2 address this point.

Second, what is the relationship between teachers' subject-matter knowledge and the frequency with which they question students? The conceptual framework predicts that teachers will ask more questions when they do not understand the subject well. Asking questions may be another way of controlling discourse. Findings 3 and 4 address this point.

Third, how does teacher subject-matter knowledge affect student verbal participation in lessons? The framework predicts that when teachers understand their subject well, their students will more actively participate in classroom conversation. Findings 5 and 6 discuss this prediction.

Fourth, what are the effects of teacher knowledge on the types of questions that are asked in class? The model predicts that when teachers understand their subject-matter well, they will ask questions which permit greater student flexibility in response. Finding 7 examines the effects of subject-matter knowledge on the cognitive level of teacher questions.

The analyses which follow do not report statistical significance, for several reasons. First, the data do not represent an empirically perfect and balanced sample of discourse. Data were collected in natural settings. The teachers and students knew that they were being audiotaped, but the class

activities, the patterns of participation, and the topics of the lesson were under the control of the speakers, not the researcher. Hence, for example, although nine laboratory sessions were taped, no labs were taped in low-knowledge classes for Ms. Nims.⁴ Second, there is a strong interaction between the teacher and most of the discourse measures used. For example, Ms. Town tended to talk more than Ms. Ross on most measures, including number of questions, number of utterances, and average utterance duration. Third, although data were collected for a large number of utterances (over 4000 utterances varying in duration from less than one second to several minutes), characteristics of the data make the application of parametric statistics problematic. Speech durations, for example, are highly skewed, with most utterances lasting six seconds or less. Finally, from a sociolinguistic perspective, conversation consists of topically-related utterances; any analysis of utterance data which relies upon an assumption of statistical independence is internally inconsistent.

Because the characteristics of classroom discourse depend on the type of activity that is taking place in the lesson, it is not enough to compare utterances in high-knowledge classes with utterances in low-knowledge classes. When that analytic strategy is used, differences in discourse attributable to classroom activity obscure differences attributable to teacher knowledge level. Many of the findings that follow are broken down by classroom activity.

In a similar fashion, I looked for teacher-specific effects on each of the Findings; where effects were found, they are noted. Where they were not found, pooled data are presented. My intention is not to suggest that pooled-teacher data represent a random sample of teachers, nor that the teachers' discourse strategies were identical. Breaking all statistics down by teacher

and activity, however, would give the reader little sense of trends in the data.

Amount of Teacher Talk

Finding 1: Teacher talk as a percentage of class time. Table 1 displays teacher talk as a percentage of total class time, for all teachers combined. The data suggest that the teachers tended to talk more in lectures and recitations (shown here as the combined activity, "Lectures") when they were subject-matter knowledgeable than when they were not. This finding is consistent with the conceptual framework. The data suggest that the opposite effect occurred during Laboratories: teachers talked more when they were topic knowledgeable. This finding was not expected, and is explored elsewhere in more detail using discourse analysis (Carlsen, 1990).

Statistics for the other four categories in Table 1 are based on fewer minutes of observation. Group work, Routines and Seatwork activities had more teacher talk in low-knowledge lessons (although the size of the difference for routines was negligible); Instructions (for laboratory and other activities) had more teacher talk in high-knowledge classes. Overall, these statistics are consistent with the prediction of the conceptual framework that teacher knowledge is related to teacher talk, although the knowledge effect in Laboratories is opposite the predicted effect.

Finding 2: The duration of teacher utterances. Table 2 contains data on the average duration of teacher utterances, by class activity and teacher knowledge level. Although the differences were small, individual utterances were longer in low-knowledge classes for six of the seven activities listed in Table 2. Teachers tend to "hold on" to their speaking turns for slightly longer periods in low-knowledge classes. This finding is consistent with the

Table 1

Teacher Talk as a Percentage of Class Time (by Activity)

Activity	Number of Minutes of Instruction		Percent of Time Teacher Talked		Teacher Knowledge Level of Classes with Most Teacher Talk
	High- Knowledge	Low- Knowledge	High- Knowledge	Low Knowledge	
	Lessons	Lessons	Lessons	Lessons	
Group work	73 min.	169 min.	44.7%	53.3%	LOW
Instructions	82	102	70.0	61.3	HIGH
Laboratories	182	103	56.5	48.7	HIGH
Lectures	269	139	64.9	88.5	LOW
Routines	46	50	55.5	56.3	LOW
Seatwork	42	32	41.1	47.8	LOW
Total	694	595	59.1	62.0	LOW

Note: "Percent of time teacher talked" is the sum of the durations of all sequences of teacher talk, divided by the number of minutes of instruction. Sequences of teacher talk were measured in seconds from an initial teacher vocalization to the beginning of the next pause in teacher talk of three seconds or more. Note that, unlike the definition of utterances (as used in Table 2), sequences ignore overlapping student talk.

Table 2

Mean Duration of Teacher Utterances by Activity (in seconds)

Activity	Type of Lesson				Teacher Knowledge of Classes with the Most Talk
	High-Knowledge		Low-Knowledge		
	mean	S .D. (N) ^a	mean	S.D. (N)	
Group work	9.78	10.3 (102)	10.25	22.5 (525)	LOW
Instructions	14.48	28.2 (237)	15.12	23.8 (248)	LOW
Laboratories	9.81	15.1 (630)	7.22	13.0 (415)	HIGH
Lectures	15.12	29.1 (693)	15.37	23.9 (479)	LOW
Routines	14.51	34.7 (106)	15.43	37.4 (110)	LOW
Seatwork	5.43	5.2 (190)	8.62	10.7 (107)	LOW

a Number of teacher utterances, all teachers combined.

conceptual framework of the study. Once again, the situation in Laboratories differed from that in other classes: in labs, the teachers spoke for longer periods of time on high-knowledge days.

The rate of speech in number of words per second and number of transcribed letters per second were also computed. Teacher knowledge level had no effect on either measure of the rate of teacher speech. Given that finding, a more labor-intensive calculation of speech rate in phonemes was not undertaken.

Rate of Teacher Questioning

Finding 3: Rate of teacher questioning. Table 3 presents teacher questioning rates across all activities for each of the four teachers.⁵ For three of the four teachers, questioning rates were highest in classes on low teacher-knowledge topics. This finding is consistent with the conceptual framework, which predicts that teachers will ask questions more frequently in low-knowledge lessons than in high-knowledge lessons.

The trend for Ms. Kaye was clearly different from that of the other teachers: the average questioning rate in her high-knowledge lessons was much higher than the rate in her low-knowledge lessons. Inspection of questioning rates revealed that much of the effect was attributable to one lessons, which had a teacher questioning rate twice as high as any of Ms. Kaye's other seven lessons. The anomalous lesson occurred early in the school year, when Ms. Kaye was struggling to establish control of her class. Early in the lesson, the teacher stopped class and sent a disruptive student to the office, then began a 43 minute recitation with frequent low cognitive level teacher questions. In this case, problems of classroom management rather than teacher knowledge appear to have prompted a highly-inquisitorial teacher discourse strategy.

Table 3

Rate of Teacher Questioning by Teacher (questions/min)

Teacher	Type of Lesson				Teacher Knowledge of Classes with the Highest Ques. Rate
	High-Knowledge		Low-Knowledge		
	mean	S.D. ^a	mean	S.D.	
Kaye	0.99	0.52	0.38	0.23	HIGH
Nims	0.55	0.33	0.93	0.20	LOW
Ross	0.35	0.44	0.58	0.64	LOW
Town	0.73	0.40	0.98	0.55	LOW

a Between-lesson deviation. $n=4$ for all cells except Ross Low-Knowledge, where $n=2$.

Finding 4: Rate of teacher questioning during whole-class instruction.

Although imbalances in sampling across teacher knowledge levels and activities prohibited activity-by-activity analysis of the effects of teacher knowledge on teacher questioning rates, combining communicatively-similar activities permitted some further analysis of teacher questioning rates. For example, combining all lectures, recitations, and teacher-conducted reviews of student homework and examination papers showed that these types of whole-class instruction were characterized by high rates of teacher questioning. The trend described in Finding 3 for all activities pooled also characterizes this subsample of all activities: three of the four teachers asked questions more frequently in low-knowledge classes. Again, Ms. Kaye was the one exception.

Student Questioning Rate

Finding 5: Rate of student questioning by activity. Table 4 presents student questioning rates and shows that the rate at which students ask questions to the teacher is highly dependent on which class activity is taking place. The highest average questioning rates occurred during laboratory activities, followed by seatwork, lectures, and teacher instructions. Students asked questions most frequently when whole-class instruction was not occurring. This finding underscores the necessity of contextualizing data about student talk within classroom activities.

For comparative purposes, Table 5 presents teacher questioning rates for the same activities. Across classrooms and activities, teacher questioning rates were almost always much higher than student questioning rates. The one exception to this generalization was laboratory exercises, where the rate of student questions to the teacher (0.702 questions/min.) exceeded the teacher rate to students (0.600 questions/min.). Again, this suggests that lab

Table 4

Rate of Student Questioning by Activity (questions per minute)

Activity	Total Number of Classes	Total Number of Minutes	Total Number Questions	Mean Questioning Rate ^a
Group work	10	242	16	0.066
Instructions	24	184	19	0.103
Laboratories	9	285	200	0.702
Lectures	18	408	102	0.250
Routines	25	96	1	0.010
Seatwork	5	74	39	0.527

a This is the overall questioning rate, calculated over all classes and teachers. It is equal to the third column divided by the second column.

Table 5

Rate of Teacher Questioning by Activity (questions per minute)

ActType	Total Number of Classes	Total Number of Minutes	Total Number Questions	Mean Questioning Rate ^a
Group work	10	242	75	0.310
Instructions	24	184	73	0.397
Laboratories	9	285	171	0.600
Lectures	18	408	556	1.363
Routines	25	96	4	0.042
Seatwork	5	74	63	0.851

a This is the overall questioning rate, calculated over all classes and teachers. It is equal to the third column divided by the second column.

activities warrant attention as a special case in the study of communication in science classrooms. Although student group work was in some ways organizationally similar to laboratory exercises,⁶ it was characterized by low rates of student questioning and moderate rates of teacher questioning.

Finding 6: Student questioning in student group activities and lectures.

Imbalances in sampling prohibited an activity-by-activity analysis of the effects of teacher knowledge on student questioning. Nevertheless, by combining similar activities and pooling the data from all teachers, a rough test of the effects of teacher knowledge can be achieved. For example, when all activities involving student groups are pooled, the student questioning rate in high teacher knowledge lessons was 0.510 questions/minute, and in low-knowledge lessons was 0.391 questions/minute. Table 6 displays the relationship between teacher knowledge and student questioning rates in lectures and recitations. Again, student questioning rates were highest in high teacher knowledge lessons.

Cognitive Level of Teacher Questions

Finding 7: Ratio of high-level to low-level questions. Table 7 presents data on the cognitive level of teacher questions, by teacher and subject-matter knowledge. Each of the four teachers asked relatively more high cognitive level questions when they were teaching familiar topics. Differences between teachers were greater than subject-matter related differences, however.

Assessment of the cognitive level of teacher questions was done, as noted earlier, by the investigator through discourse analysis of questions in their instructional context. This method contrasts sharply with the relatively

Table 6

Student Questioning Rate by Teacher Subject-Matter Knowledge
in Lectures (questions/minute)

Teacher Subject- Matter Knowledge	Minutes of Instruction	Number of Questions	Questioning Rate
High	269	77	0.286
Low	139	25	0.180

Table 7

Teacher Questions by Cognitive Level (all activities)

Teacher	Frequency of Teacher Questions					
	High-Knowledge Lessons			Low-Knowledge Lessons		
	Ratio			Ratio		
	High-Cog	Low-Cog	High:Low	High-Cog	Low-Cog	High:Low
Kaye	43	168	0.26	8	76	0.11
Nims	48	67	0.72	71	119	0.60
Ross	15	31	0.48	17	42	0.41
Town	72	106	0.68	33	66	0.50
Total	178	372	0.59	129	303	0.46

decontextualized semantic analysis of questions commonly used in process-product research on teaching. Although the findings on the effects of teacher knowledge on question cognitive level are intriguing, the possibility of investigator bias in coding cannot be dismissed.

Discussion

The findings presented in this paper are selected views of discourse from a microanalytic perspective. This analysis of the effects of teacher subject-matter knowledge on classroom language does not clearly indicate that new biology teachers deliver better (or worse) instruction on familiar topics than on unfamiliar topics. Little can be concluded about the quality of instruction by looking at individual utterances.

Nevertheless, this study suggests several ways in which teacher subject-matter knowledge is a critical contributor to the language of the science classroom. First, an heretofore undocumented relationship is identified between teacher subject-matter knowledge and the cognitive level of teacher questions. When these teachers were not topic-knowledgeable, they were more likely to rely upon low-level questions. Second, a relationship is noted between teacher knowledge and teacher domination of the speaking floor. When topic-knowledgeable, these four teachers gave their students more opportunities to speak. This raises the provocative possibility that naturally extended teacher wait times may be a function of teacher knowledge, and that wait-time training in the absence of subject-matter strength may be a wasted effort.⁷ Third, this study points out that teachers ought not view questions as sociolinguistically inert. Teachers may ask more questions when they are unfamiliar with the content that they are teaching, and one effect of high levels of teacher questioning--particularly low-level teacher questioning--

appears to be a reduction in students' opportunities to speak.

While conducting these analyses, the data were examined in other ways, with less consistent results. For example, when student questions over all activities were pooled and displayed by teacher subject-matter knowledge, no consistent knowledge effect was seen. Activity-related differences in student questioning rate obscured differences related to teacher knowledge. Clearly, sensitivity to context is critical in discourse analysis even when relatively low-inference measures are used.

These results provide support for a sociolinguistic model of the effects of teacher knowledge on classroom discourse. Nevertheless, this microscopic view of discourse does not prove that teacher knowledge has a big impact on classroom discourse. Part of the difficulty in supporting such a claim is that the types of classroom instruction that teachers choose vary according to the teacher, the students, and the subject matter being studied. In order to make convincing assertions about the frequency of teacher questioning, the types of questions teachers ask, and student participation in lessons, one would need to observe many more lessons. Powerful multivariate techniques might be able to sort out the relative contributions to variance by teacher, lesson, academic level of the students, classroom activity and other factors. Several of the measures considered in this paper would need to be transformed or more carefully controlled in order to meet some of the assumptions of these methods, such as normality and homogeneity of variance.

An alternative approach to the problem of quantitative measurement of teacher and student verbal behaviors would be to more carefully delimit the teacher's task and the verbal behavior of the students. For example, one might ask teachers with different levels of subject-matter knowledge to answer

scripted questions delivered by trained student actors (for an example of such a teaching experiment, see Carlsen & Wilson, 1988).

The problem with both of these approaches is that they present a very distorted view of what teaching in real classrooms is like. Numerical analysis of discourse obscures the give-and-take that occurs in actual conversation. Experimental manipulations ignore much of what we know about teaching. The language that teachers and students use is based on routines and shared meanings that are negotiated over time. When a researcher tells a teacher or her students to do certain things, the parameters of discourse are no longer defined by the natural inhabitants of the classroom. Some of those parameters are defined by an outsider.

Although this numerical analysis offers insights concerning the effects of teacher knowledge on classroom discourse, it should be viewed as only one part of a more comprehensive multimethodological analysis of classroom language, which also attended to the curricular decisions of teachers and the substance of discourse.

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1. I do not mean to suggest that a computational algorithm can extract utterances from a transcript without reference to any linguistic theory. The transcript used as data for such an algorithm is the product of theory-based human interpretation (Ochs, 1979; Mishler, 1984). At best, an algorithm may be thought of as a tool for subsequent interpretation that is unusually theoretically explicit (Carlsen, 1989b). In this study, pauses and changes in speaker are more heavily weighted than they would be in a conventional analysis.

2. Questions were coded by the investigator as procedural or instructional. Procedural questions were excluded from the analysis in this paper. Instructional questions were further coded by cognitive level. Low cognitive level questions were questions that could be answered by recalling something stated earlier in the lesson or in an assigned reading. High cognitive level questions required evaluation, synthesis, computation, or other higher order thinking. Although this definition may seem fairly straightforward, what may appear on the surface to be a high level question may simply require recall from the previous day's lesson. Therefore, cognitive level coding was done only after: a) listening to the lesson at least three times, b) reviewing the teacher's lesson plans and related instructional materials, and c) interviewing the teacher about the content and the history of the lesson. The pilot study revealed that understanding the context of each question was

critical to cognitive level coding. This context includes the material in prior lessons, assigned readings, the communicative habits of speakers, and discourse from earlier in the lesson.

3. A more complete description of the software and its underpinnings in transcription theory and computer science is found in Carlsen (1989b).

4. To provide anonymity in such a small study, the four teachers were given pseudonyms and a coin toss determined the titles of all four teachers. In reality, two of the teachers were female and two were male.

5. The rates of teacher and student questioning were calculated using only instructional questions. Procedural questions (e.g., "When is this homework due?") were excluded.

6. As classified in this study, group work required two or more students to work together on reports, puzzles, art projects or similar activities, but did not include any data collection or the use of scientific equipment.

7. Space limitations preclude an extended development of this speculation, but it may be summarized as follows: 1) subject-matter knowledgeable teachers naturally wait longer after questions for student responses; 2) long teacher wait times serve as cues to students concerning the types of responses that the teacher expects; 3) wait time training in the absence of teacher subject-matter knowledge changes these cues, encouraging student responses that are inappropriate for the teacher's knowledge; and 4) the effects of wait time training decay with time.